TALKS ON MEDICAL [EL]ECTRICITY AND BATTERIES·

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PLAIN TALKS

ON

ELECTRICITY AND BATTERIES.

BIGELOW.

TO

A. S. B. AND J. S. B.

PLAIN TALKS

ON

ELECTRICITY AND BATTERIES

WITH THERAPEUTIC INDEX.

FOR GENERAL PRACTITIONERS AND STUDENTS OF MEDICINE.

BY

HORATIO R. BIGELOW, M.D.,

PERMANENT MEMBER OF THE AMERICAN MEDICAL ASSOCIATION; FELLOW OF THE BRITISH GYNÆCOLOGICAL SOCIETY; FELLOW OF THE AMERICAN ELECTRO-THERAPEUTIC ASSOCIATION; MEMBER OF THE PHILADELPHIA ELECTRO-THERAPEUTIC SOCIETY; MEMBER OF THE ANTHROPOLOGICAL AND BIOLOGICAL SOCIETIES, OF WASHINGTON, D. C.

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PREFACE.

My intention has been to give the general practitioner and student a plain, practical presentation of a difficult subject. Ethical adornment and scientific discussions have been avoided. Long, technical terms have not been used when possible to do without them. There may not be much of originality in the endeavor. Few books nowadays are the absolute brain outcome of the author. Works that I have drawn from largely, and which I cordially commend to any one who may desire to "read up," are Massey: "On Electricity in the Diseases of Women;" Rohé and Liebig: "The Practical Application of Electricity in Medicine and Surgery;" the writings of Dr. Wm. I. Morton; Sylvanus Thompson: "Elementary Lessons in Electricity;" Forbes: "Lectures on Electricity;" Tripier's writings (French); Erb's works (German), and McClure's little book on "Static Electricity," etc. I have written a small book on "Gynæcological

Electro-therapeutics," which may be useful to those who may wish to acquaint themselves with the method of Apostoli. The Therapeutic Index is largely that given by Tripier. We have not yet a perfect faradic battery. I give a drawing of one only, but good ones, and cheaper than the Engelmann, are made by the Waite & Bartlett Mfg. Co. and by Flemming. The little pocket battery of Gaiffe I have found very convenient. The DuBois-Reymond coil is also valuable.

Bingham House,
Philadelphia.

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CHAPTER I.

DEFINITIONS.

Electro-motor Force is that which sets electricity in motion, or the difference of potential between two points, the transfer always taking place from the higher to the lower. This "electro-motive force," or that which tends to move electricity, must not be confounded with *electric* "*force*," or that force with which electricity tends to move matter. "Just as in water-pipes a *difference* of *level* produces a *pressure*, and the pressure produces a *flow* so soon as the tap is turned on, so *difference of potential* produces *electro-motive force*, and electro-motive force sets up a *current* so soon as a connection is made for the electricity to flow through." The symbol used is E. M. F. Electro-motive force is measured in

Volts.—One volt will send a quantity of elec-

tricity, known as a *coulomb*, through one *ohm* of resistance.

Resistance.—This is the measure of the value of the obstruction to the free transmission of electricity. It is the *inverse of its conductibility.* In fifty healthy people Wolfenden found the resistance to be 4000 and 5000 ohms with a current of 15 volts. In eighteen cases of Grave's disease he found the resistance to vary between 500 and 1500 ohms. There is also a resistance, which is variable, but ought not to exceed 1.15 or 2. ohms, within the cell itself. Then the connecting wire and the electrode also offer some obstruction. The measure of resistance is the

Ohm.—And *Ohm's* law is that *the current in any conductor is equal to the electro-motive force between its ends divided by its resistance.* $C = \frac{E}{R}$, or 1 ampère $= \frac{1 \text{ volt}}{1 \text{ ohm}}$.

Intensity.—The intensity of a current is the same in all points of the circuit, and is really the quantity of electricity passing any part of the circuit in a second. Its measure is the

Ampère, but for medical purposes we use the thousandth part of it, which is called a *milliampère.*

Tension.—This is the property of electricity to give effects similar to those of static electricity. It is that which gives impulse to the electric fluid. This term is so often misused that it should be

dropped altogether. It has even been confounded with potential and electric force.

Potential.—This is the measure of the work done, and is expressed in centimetres, grammes. The standard of reference is the earth, whose potential is supposed to be zero. The *potential* characterizes the electric condition of a body, just as *temperature* does its *heat*. *The potential at any point is the work that must be spent upon a unit of positive electricity in bringing it up to that point from an infinite distance.* Since the surface of a conductor must be everywhere at the same potential, it is on this account called an *equipotential surface.*

Current.—The passage of electricity through a body constitutes a *current.*

Induction.—If we rub a glass ball with silk to electrify it, and hold it near to a body that has not been electrified, the conductor itself, which has not been rubbed, will behave at its two ends as an electrified body. The end nearest the ball will be charged negatively, and the farthest end will be positive. A positive charge attracts negative and repels positive, and this influence may be exerted at a distance from the body. This is induction or influence. Faraday discovered that the *air* plays a most important rôle in induction. So we may say that induction is the power of an electrified body to act through the molecules of the air on

another body decomposing its fluid and attracting its opposite electricity.

Dielectrics.—The property of certain substances to permit an inductive electric influence to act across or through them, led Faraday to call such substances Dielectrics. "All dielectrics are insulators, but equally good insulators are not necessarily equally good dielectrics." Glass is a better dielectric than ebonite, or paraffin, or air.

Circuit.—This is the complete path through which the current flows from its source back again.

Polarization.—A battery is said to be polarized when a film of hydrogen bubbles is found sticking to the copper pole, thus destroying the effective amount of surface of the copper plate, so that the strength of the current, after a few seconds, falls off materially. The effects of polarization are: that it weakens the current by the increased resistance which it offers to its flow, and that it weakens the current by setting up an opposing *electro-motive force*, since hydrogen, being almost as oxidizable a substance as zinc, produces a difference of potential, which would tend to start a current in the opposite direction to the true current.

Cataphoresis.—The method of introducing medicinal agents into the system by the galvanic current.

Electrolysis is the action of a current when

passing through a liquid of decomposing it, so that the *metal* will go to the *negative* electrode and the *radical* to the *positive.* Faraday called the *positive* plate the *anode*, and the negative plate the *kathode.* The solution through which the current flowed he called an *electrolyte.* Upon animal tissue the electrolytic effects are very marked. The alkalies go to the negative pole and the acids to the positive. Hence the necessity of using a *platinum*, *gold*, or *carbon electrode* in the positive pole when a concentrated current is being used.

Electricity.—This is a form of energy, just as heat is. When a bar of iron, one end of which is resting upon a block of ice, is heated, a change takes place; an energy is transmitted along the bar, which has no exact definition. Magnetism, which may possibly be a mere circular current of electricity of the ultimate molecule, is another form of energy, and as light is also an energy due to molecular change of the ether, so we may correlate all of these forms of energies. The conservation of force teaches us that these energies may appear under other correlate forms, so that a motion once originated is never lost. If we can imagine a current started in a conductor frozen to 273° Centigrade minus, where molecular movement is at rest, such a current would be perpetual, because there would be no resistance. Gravity is another instance,

and this illustrates resistance perfectly. The falling body develops an energy peculiar to itself, movement, which may be transformed into heat. The earth develops energy in drawing the body to itself. If the book rest on the table, the earth still endeavors to attract it, and the book also endeavors to fall to the earth, but there is an interposed resistance, the table, and as a result we have pressure. Only by the supposition of a surrounding ether can we account for induction, magnetic fields and optical phenomena. All of Oersted's laws, perfected and worked out by Faraday, out of which grew the telegraph, telephone, phonograph and dynamo machines, are based upon these questions of inductive currents. Oersted found that if a current ot electricity were passed *over* a magnetic needle, the needle was deflected in a certain direction, and if the current of electricity was passed under the needle it was deflected in another direction. He also found that a magnet could induce a current by induction in another current; that a current could induce magnetic action in a bar of iron, and that one current could influence another. This is the whole principle of dynamos, which are fashioned upon the knowledge we have that, when a bar of iron is wrapped about with wire and a current started through it, not only is the iron magnetized, but the action of the magnetized iron greatly

intensifies the current. So arose Gramme's rings and the armature.

Galvanometer.—When a magnetic needle is suspended in a ring through which a current flows, every part of the ring carrying the current is trying to drive the north pole of the needle through the middle of the ring in one direction, and the south pole in the other direction, so that the compass needle in the centre of the ring would have a strong tendency to set with its length along the axis of the ring. Now if we have a coil of 1000 turns of wire, the current will only require the one-thousandth of the strength to produce the same effect. This is the principle of the galvanometer for measuring small currents. "If we give the wire a turn around the compass needle so that the current flows over the needle from south to north, and under it from north to south, the two actions reinforce each other, both turning the north end of the needle to the west. If we repeat the operation by making a number of turns of wire surround the compass needle, we multiply the effect, provided we take care that successive turns of wire are insulated from each other, which is done by covering the wire with cotton, or better, with silk, or even gutta percha or India rubber. By this device the current must go round each turn completely."

"**Physiological Actions.**—Currents of elec-

tricity passed through the limbs affect the nerves with certain painful sensations, and cause the muscles to undergo involuntary contractions. The sudden rush of even a small charge of electricity from a Leyden jar charged to a high potential, or from an induction coil, gives a sharp and painful *shock* to the system. The current from a few strong Grove's cells, conveyed through the body by grasping the terminals with moistened hands, gives a very different kind of sensation, not at all agreeable, of a prickling in the joints of the arms and shoulders, but not producing any spasmodic contractions, except it be in nervous or weakly persons, at the sudden making or breaking of the circuit. The difference between the two cases lies in the fact that the tissues of the body offer a very considerable resistance, and that the difference of potential in the former case may be many thousands of volts; hence, though the actual quantity stored up in the Leyden jar is very small, its very high E. M. F. enables it at once to overcome the resistance. The battery, although it might, when working through a good conductor, afford in one second a thousand times as much electricity, cannot, when working through the high resistance of the body, transmit more than a small fraction, owing to its limited E. M. F.

"After the discovery of the *shock* of the Leyden

jar by Cunæus in 1745 many experiments were tried. Louis XV of France caused an electric shock from a battery of Leyden jars to be administered to 700 Carthusian monks joined hand in hand, with prodigious effect. Franklin killed a turkey by a shock from a Leyden jar.

"In 1752 Sulzer remarked that 'if you join two pieces of lead and silver, and then lay them upon the tongue, you will notice a certain *taste* resembling that of green vitriol, while each piece apart produces no such sensation.' This galvanic taste, not then suspected to have any connection with electricity, may be experienced by placing a silver coin on the tongue and a steel pen under it, the edges of them being then brought into metallic contact. The same taste is noticed if the two wires from the poles of a voltaic cell are placed in contact with the tongue.

"Ritter discovered that a feeble current transmitted through the eyeball produces the sensation as of a bright *flash of light* by its sudden stimulation of the optic nerve. A stronger current transmitted by means of moistened conductors attached to the battery terminals gave a sensation of blue and green *colors* in flowing between the forehead and the hand. Helmholtz, repeating this experiment, observed only a wild rush of color. Dr. Hunter saw flashes of light when a piece of metal

placed under the tongue was touched against another which touched the moist tissues of the eye. Volta and Ritter heard musical sounds when a current was passed through the ears; and Humboldt found a sensation to be produced in the organs of smell when a current was passed from the nostril to the soft palate. Each of the specialized senses can be stimulated into activity by the current. Man possesses no specialized sense for the perception of electrical forces, as he does for light and for sound; but there is no reason for denying the possibility that some of the lower creatures may be endowed with a special electrical sense."—(*Sylvanus Thompson.*)

CHAPTER II.

STATIC ELECTRICITY.

Known also as frictional or *Franklinic.*

At least six centuries B. C., it was noticed that amber when rubbed with silk attracted light bodies. Somewhat later the same properties were found to belong to sulphur, sealing wax and glass.

We have two kinds of electricity: that which is generated by rubbing glass with silk, which we call *vitreous*, and that from rubbing sealing wax with flannel, which is known as *resinous.* Bodies charged with the same electricity repel each other.

For convenience alone, we regard electricity as a fluid, of which there are two kinds, positive and negative.

Now when we rub the sealing wax with a bit of flannel, we do not produce negative electricity *alone*, since the flannel becomes positive, while the sealing wax is negative.

All static machines have for their end the separation of these two electricities, and are composed of two parts, one for generating electricity and the other for collecting it.

Biot, Cavendish and others showed that electricity at rest, or static electricity, resides in the surface of bodies which are charged with it, so that some authorities were led to believe that frictional electricity never penetrated beneath the skin, nor produced directly any effect upon the deeper tissues. We are indebted to Dr. W. J. Morton, of New York, for what seems to me to be a very thorough refutation of these opinions.

He demonstrates that a single spark represents a muscular energy expended equal to raising 1 pound 1 foot per second, and he goes on to say: "But I can easily give, say, 5 sparks per second. The muscle therefore raises [referring to one of his experiments.—Ed.] 5 pounds per second, and to raise 550 pounds (the unit of horse-power) will require 110 seconds, or about 2 minutes. The actual work, therefore, capable of being accomplished by the muscle under the stimulus of the spark is at the rate of 1 horse-power every 2 minutes, or ½ horse-power per minute. . . .

"That frictional electricity, when static, resides upon the surface is one way of making the statement. To avoid argument we will admit it. We will say, then, that the person sitting upon the insulated stool receives the electric charge upon the surface.

"But while bringing forward one fundamental law

of electricity, Dr. Starr ignores another one equally fundamental, which is that the potential at all points of a conductor on which electricity is at rest must be uniform; if it were not, there would be a flow between the two unequal potentials until it became uniform; hence the potential inside a conductor has the same value as at any point on the surface.

"It follows that at the moment of discharge (spark) the equalizing of the potentials proceeds from and to all parts of the conductor (human body), inside and outside, and we here have the current which produces the effects on nerve and muscle. And the conducting power of the charged conductor is proportional, not to the surface, but to the mass of the conductor, for a solid rod of a given diameter will convey a current which would melt a thin tube of the same diameter.

"Given, then, a surface charge upon the body, and the first spark changes the entire situation. The spark is a current, but it is only the air part of the current—the evidence of the breaking down of the strain in the fluid dielectric; the remaining continuity of the current is *in* the patient's body, not *on* it (for the potential is uniform), in the chain going from the platform to the machine, and so on up to the initial electro-motive force of the Holtz machine, and around again in a closed circuit to the ball electrode which gave the spark. The conditions

do not vary essentially from those existing in a galvanic cell or a storage battery. When we close the circuit we get the current, and it is this current which, localized by an electrode, traverses the human body at any desired point—a current of, say, 50,000 volts as against 1 volt of a Daniell's cell—put to work to overcome the resistance of, say, 2500 ohms of the body; a resistance so trivial in comparison with the voltage or pressure that it may be disregarded entirely—a current oscillating (alternating) 100,000 to 1,000,000 times per second, compensating, as regards its physiological activity, for its loss in quantity, by its enormous electro-motive force and by its exceeding rapidity. The wonder would be that nerve and muscle and all tissues should not be stimulated. The fact is that they are. And Dr. Starr's entire structure, based upon static charge, falls to the ground in the light of the discharge and its accompanying current and physiological effects, and he should alter his apparently thoughtless dictum and write, 'frictional electricity, as commonly administered, penetrates beneath the skin and produces directly effects upon the deeper tissues.'

"In conclusion, to leave facts and venture a single opinion, I believe that no form of electricity 'penetrates' more deeply than the static; and, premising a powerful machine, a powerful spark, a conservative expectation as to results, a fair comparison

with galvanism and faradism, an intelligent selection of cases, and a fair amount of skill in administration, I believe that no form of electricity equals it in curative effect."

I give this long extract from Dr. Morton, not only because he is a recognized authority, but because, too, I feel sure that static electricity in the near future will play a most important rôle in electro-therapeutics. With static induction, which will be described farther on, we have a current of much greater value and wider scope than that of the induction coil, known also as Faradic, and I could wish that every reader of this book should also read a very remarkable article, published by Dr. Morton in the New York *Medical Record*, January 24th, 1891, on the "Franklinic Interrupted Current."

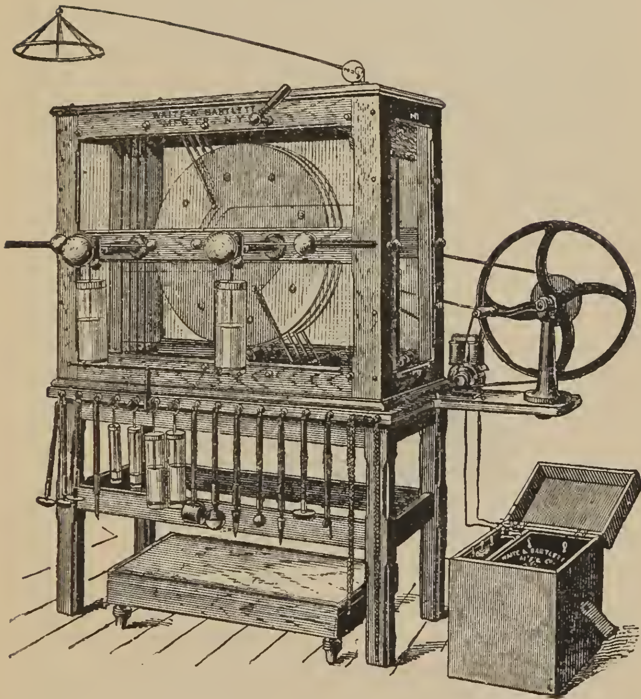
Leyden Jars.—"These are condensers, consisting simply of a glass jar, covered inside and outside, except near the neck, with tin-foil. On top of the jar is a brass knob in metallic communication with the inside coating, but insulated from the outside metal by means of a wooden stopper, through which the knob passes." By condenser we understand, simply, a holder of electricity. To charge the jar, the knob is held to the prime conductor of an electrical machine, the outer coating being either held in the hand or connected to "earth" by wire or chain. When a + charge of electricity is imparted

thus to the inner coating, it acts inductively on the outer coating, attracting a — charge into the face of the outer coating nearest the glass, and repelling a + charge to the outside of the outer coating, and thence through the hand or wire to earth. After a few moments, the jar will have acquired its full charge, the outer coating being — and the inner +. Properly cared for, the jar will retain its charge for days. By establishing a circuit between the outer and the inner coating, the jar will be discharged, and a bright spark will pass between the conductors.

Dielectric Strain.—This hypothesis, enunciated by Faraday, is, *that electric force acts across space in consequence of the transmission of stresses and strains in the medium with which space is filled.* All dielectrics across which inductive actions are at work, are thereby *strained;* that is, there is an alteration of form or volume due to the application of a stress, and it is believed that electrical phenomena are due to stresses and strains in the so-called "ether," the thin medium pervading all matter and space, whose highly elastic constitution enables it to convey to us the vibrations of light, though it is millions of times less dense than the air. The glass between the two coatings of tin-foil in the Leyden jar is actually strained or squeezed between the attracting charges of electricity.

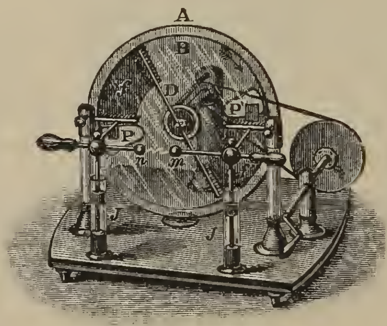
MACHINES.

Fig. 1.



Holtz's Influence Machine.—The action of this machine is not altogether easy to grasp, though in reality simple enough when carefully explained. The machine in its latest form consists (Fig. 2) of two plates, one, A, fixed by its edges; the other, B, mounted on an axis, and requiring to be rotated at a high speed by a band and driving pulley.

Fig. 2.



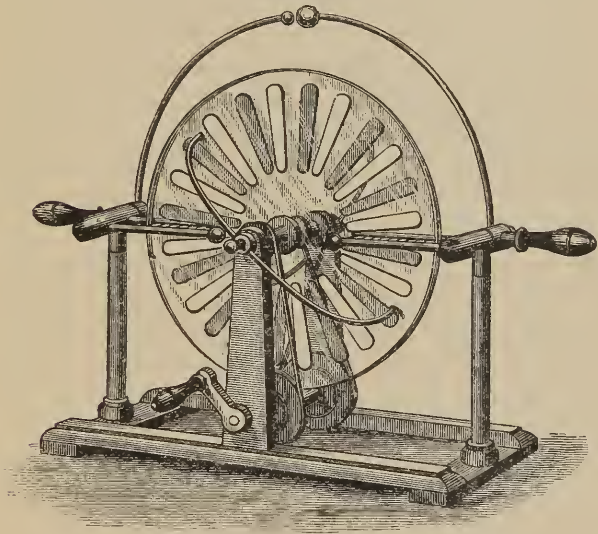
There are two holes or windows, P and P′, cut at opposite points of the fixed plate. Two pieces of varnished paper, f and f', are fastened to the plate above the window on the left and below the one on the right. These pieces of paper or *armatures* are upon the side of the fixed plate away from the movable disc, or, as we may say, upon the back of the plate. They are provided with narrow tongues

which project forward through the windows toward the movable disc, which they nearly touch with their protruding points. The disc must rotate in the opposite direction to that in which these tongues point. On the front side of the moving disc, and opposite the forward edges of the two armatures, stands an oblique metal conductor, D, which need not be insulated. It has metal *combs* or spikes projecting toward the disc. On the right and left, supported on isulating holders, are two horizontal metal combs, joined to two metal rods terminated with brass balls, *m*, *n*, which in this form of machine merely constitute a discharging apparatus, and are not concerned in the action of the machine. In some forms of Holtz machine there is no diagonal conductor, D; and as the discharging apparatus has then to serve both functions, the balls, *m*, *n*, must in these forms of machine touch one another before the machine will charge itself. To work the machine a small initial charge must be given by an electrophorus, or by a rubbed glass rod, to one of the two armatures. The disc is then rapidly rotated; and it is found that after a few turns the exertion required to keep up the rotation increases greatly; at the same moment pale-blue brushes of light are seen to issue from the points, and, on separating the brass balls, a torrent of brilliant sparks darts across the intervening space.

The action of the machine is as follows: Suppose a small + charge to be imparted at the outset to the right armature, *f'*; this charge acts inductively across the intervening glass and air upon the comb at the lower end of the diagonal conductor D, repels electricity through D, leaving the lower points negatively electrified. These discharge negatively electrified air upon the front surface of the movable disc, while the repelled + charge passes up along D, and is discharged through the upper comb upon the front face of the movable disc. Here it acts inductively upon the paper armature *f*, causing that part which is opposite the comb to be negatively charged, and repelling a + charge into its farthest part, viz., into the tongue, which slowly discharges a + charge upon the back of the moving disc. If now the disc be turned around, this + charge on the back comes over, in the direction indicated by the arrow, from the left to the right side; and, when it gets opposite the right tongue, is discharged into the armature *f'*, increasing its charge, and thereby helps that armature to act still more strongly than before. Meantime the — charge, which we saw had been induced in the left armature *f*, has in turn reacted on the upper comb, causing it to emit more powerfully than before a + charge from its points, and drawing electricity through the diagonal rod. The

combs at the two ends of this rod, therefore, both emit electrified streams of air, the upper one charging the upper portion of the front of the rotating disc positively, the lower one charging the lower

FIG. 3.



portion of the disc negatively. The back of the rotating disc is at the same time similarly charged; and the charges carried round on the back surface serve to increase the charges on the two armatures. Hence a very small initial charge is speedily raised

to a maximum, the limit being reached when the electrification of the armatures is so great that the leakage of electricity at their surface equals the gain by induction and convection. The charges let off by the spikes of the diagonal conductor upon the front surface of the moving disc are carried round and discharged into the right and left conductors of the discharging apparatus, by means of the horizontal combs which collect the charges. Two small Leyden jars are usually added to increase the density of the sparks that pass between m and n.

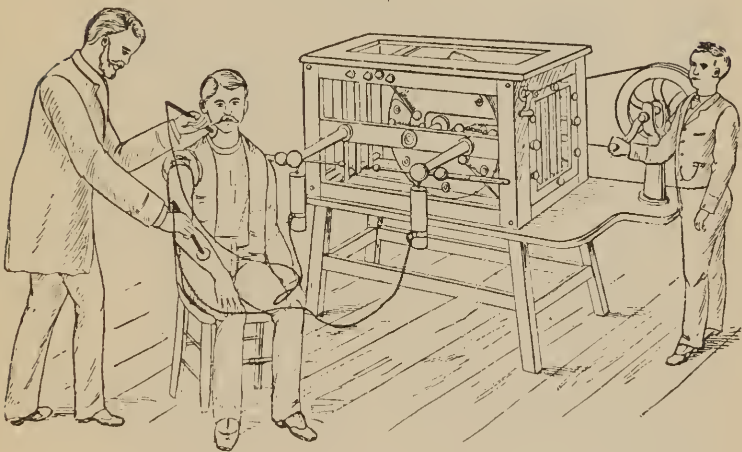
In some recent Holtz machines, a number of rotating discs fixed upon one common axis are employed, and the whole is enclosed in a glass case to prevent access of damp. A small disc of ebonite is now usually fixed to the axis, and provided with a rubber in order to keep up the initial charge. Holtz has lately constructed a machine with thirty-two plates.

Mascart has shown the interesting fact that the Holtz machine is *reversible* in its action; that is to say, that if a continuous supply of the two electricities (furnished by another machine) be communicated to the armatures, the movable plate will be thereby set in rotation, and will turn in an opposite sense.

Righi has shown that a Holtz machine can yield a continuous current like a voltaic battery, the

strength of the current being nearly proportional to the velocity of rotation. It was found that the electro-motive force of a machine was equal to that of 52,000 Daniell's cells, or nearly 53,000 volts, at all speeds. The resistance, when the machine made 120 revolutions per minute, was 2180 million

Fig. 4.

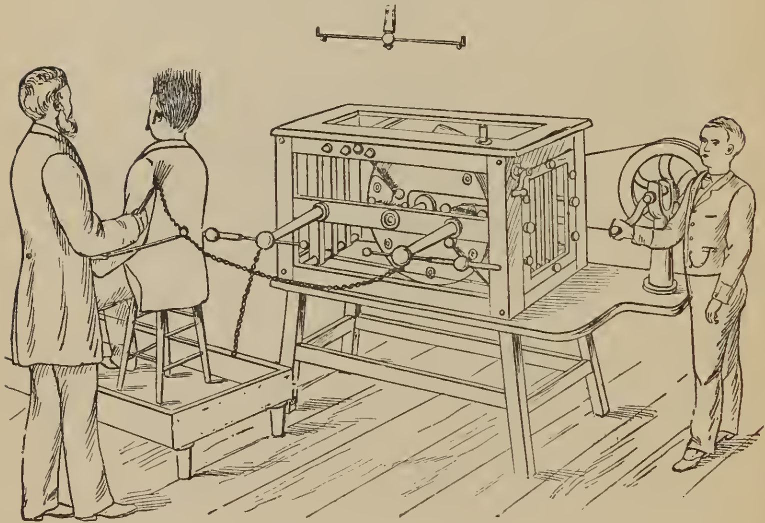


ohms; but only 646 million ohms when making 450 revolutions per minute.

The machine represented in Fig. 1, made by the Waite and Bartlett Manufacturing Company, is one of the very best, if not the best, that I know of. Prior to the early winter of 1891, I had been accus-

tomed to use a Carré machine, and a most excellent one it is too, in which the positive electricity is collected by a large cylinder collector and then utilized by the physician, the negative charge being

Fig. 5.

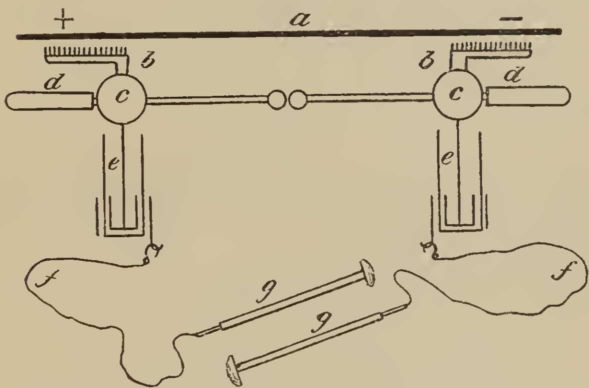


"grounded." For general use I should prefer a Holtz, however.

Static Insulation.—The patient is placed upon the insulated platform, and his body, or the stool upon which he sits, connected with the machine by

a chain. The chain must not touch the floor. The other pole of the machine is then grounded by attaching the chain to the gas or water fixture, or simply allowing the free end to rest upon the uncarpeted floor. The poles of the machine are now

FIG. 6.



"Static Induced Current." Parts ot Static Universal Electrode Separated. Person, condenser, and circuit-breaker in same circuit, connecting-rod between condensers removed, and discharging-rods of machine serving as circuit-breaker; but the circuit-breaker is in the primary circuit, and the person in the secondary. The make and break in the primary is accompanied with a current in the secondary.

separated and the machine put in rapid motion. The patient thus becomes charged with static electricity.

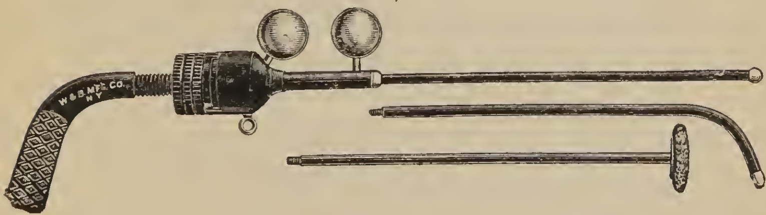
Indirect and Direct Sparks.—If the patient remains seated upon the platform, charged as before,

and a metal ball electrode, attached to a chain, is connected with the gas or water fixture, sparks will be drawn from the part of the body to which the ball is approached. This is termed the "indirect" spark. The "direct spark" is produced by connecting the electrode directly to the grounding chain, so as to place the patient in a short circuit.

Static Induced Current.—For this current the electrodes and conducting cords must be especially constructed: the metal within the sponge, if a plate, should be rolled back on itself at its edges so as to present a rounded peripheral contour, or, better still, it should be a ball of about one inch in diameter; the handle of the electrodes should be long, and made of ebonite; the conducting cord should consist of a thick strand of fine wire, well insulated by gutta percha. These precautions are necessary, owing to the great "tension" of the current and its consequent disposition to break down insulating barriers, which, in the case of ordinary currents, would suffice to confine them to their proper conductors. To use the current, bring the discharging rods (Fig. 5) of the Holtz machine into contact, removing the connecting rod which unites the two Leyden jars, and hook on the two conducting cords and electrodes. The patient need not be insulated. If, now, the wet electrodes be grasped, the machine set in motion and the discharging rods

be separated a very small fraction of an inch, the current will be felt, and may be graduated to any strength desired or bearable, and may be localized in its action internally or externally in the usual manner. By use of the insulated electrode devised by Dr. Morton, this current can be made of the greatest possible use in gynæcological work. Dr. Morton believes that this current penetrates as deeply into the human body as the galvanic current.

Fig. 7.



Electrode.—The pistol electrode (shown in Fig. 7 and invented by Dr. Morton) is suitable for the application of this current, or for any static current. The physician may, by a simple motion of the finger in operating the circuit-breaker, change his treatment from sparks to current, and *vice. versâ*, and because a great variety of terminals may be attached to it, adapting it to the customary forms of application desired for galvanism or Faradism. It will be recognized as a great convenience, in a single

sitting, to turn at once from the spark treatment to an agreeable, regulatable, efficient current for use about the face and neck, and wherever else desired to uncover the skin, or to introduce, by adding a suitable terminal electrode, within a canal or cavity.

Physical Properties of the Franklinic Interrupted Current.—Dr. Morton says: "Computing the spark interruption to be, at the least, two hundred per second, and the oscillations of each spark to be one hundred millions per second, we have a current giving twenty billions alternations per second. Vast as such a number may seem to our minds, familiar with two hundred vibrations per second, it pales before the desideratum expressed by Professor Elihu Thompson, the great authority on the properties of alternating currents, who said, in a recent lecture, 'what is needed is a machine having an alternating current making five hundred trillions of vibrations per second, which would produce many wonderful results.' If, then, I were to be asked how the Franklinic current differs from the ordinary Faradic coil, I should reply that this one difference of rate of alternations alone placed the two far apart. But it may be urged, the current of the induction coil is far greater than that of the influence machine in quantity. This is, of course, true. But at this point, in favor of the Franklinic interrupted, comes in the element of time. 'The

motor nerve,' says DuBois Reymond, ' is not stimulated by the absolute density of the current density at any given moment, but by variations from one instant to the other, and the effect produced by these rapid changes increases with their rapidity and their greatness in a given time.' Thus, in the great rapidity of the alternating (oscillating) currents of the spark discharge, particularly in rapid series, as in the Franklinic interrupted, we find the reason, despite smallness in quantity, for accomplishing work in producing nerve- and muscle-stimulation equal at least to the comparatively slow discharge of the interrupted galvanic, or the slowly oscillating induction coil. The difference may be compared to a bullet shot from a rifle, or the same bullet gently rolled across the floor."

CHAPTER III.

THE GALVANIC CURRENT.

Muscular Contractions. — In 1678, Swammerdam showed to the Grand Duke of Tuscany that when a portion of muscle of a frog's leg hanging by a thread of nerve bound with silver wire was held over a copper support, so that both nerve and wire touched the copper, the muscle immediately contracted. More than a century later, Galvani's attention was drawn to the subject by his observation of spasmodic contractions in the legs of freshly-killed frogs under the influence of the "return-shock" experienced every time a neighboring electric machine was discharged. Unaware of Swammerdam's experiment, he discovered in 1786 the fact that, when nerve and muscle touch two dissimilar metals in contact with one another, a contraction of the muscle takes place. After the frog has been killed the hind limbs are detached and skinned; the crural nerves and their attachments to the lumbar vertebræ remaining. For some hours after death, the limbs retain their contractile power. The frog's limbs thus prepared form an excessively delicate

galvanoscope: with them, for example, the excessively delicate induction-currents of the telephone can be shown, though the most sensitive galvanometers barely detect them. Galvani and Aldini proved that other creatures undergo like effects. With a pile of 100 pairs Aldini experimented on newly-killed sheep, oxen and rabbits, and found them to suffer spasmodic muscular contractions. Humboldt proved the same on fishes; and Zanotti, by sending a current through a newly-killed grasshopper, caused it to emit its familiar chirp. Aldini, and, later, Dr. Ure, of Glasgow, experimented on the bodies of executed criminals, with a success terrible to behold. The facial muscles underwent horrible contortions, and the chest heaved with the contraction of the diaphragm. This has suggested the employment of electric currents as an adjunct in reviving persons who have been drowned, the contraction of the muscles of the chest serving to start respiration into activity. The small muscles attached to the roots of the hairs of the head appear to be markedly sensitive to electrical conditions from the readiness with which electrification causes the hair to stand on end.

Conditions of Muscular Contraction.—To produce muscular contraction the current must traverse a portion of the nerve longitudinally. In a freshly prepared frog the current causes a contraction only

momentarily when the circuit is made or broken. A rapidly interrupted current will induce a second contraction before the first has had time to pass off, and the muscle may exhibit thus a continuous contraction resembling *tetanus*. The prepared frog after a short time becomes less sensitive, and a "direct" current (that is to say, one passing along the nerve in the direction from the brain to the muscle) only produces an effect when circuit is made, while an "inverse" current only produces an effect when the circuit is broken. Matteucci, who observed this, also discovered, by experiments on living animals, that there is a distinction between the conductivity of sensory and motor nerves,—a "direct" current affecting the motor nerves on making the circuit, and the sensory nerves on breaking it; while an "inverse" current produced inverse results. Little is, however, yet known of the conditions of conductivity of the matter of the nerves; they conduct better than muscular tissue, cartilage or bone; but, of all substances in the body, the blood conducts best. Powerful currents, doubtless, electrolyze the blood to some extent, coagulating it and the albumin it contains. The power of *contracting* under the influence of the current, appears to be a distinguishing property of *protoplasm* wherever it occurs. The amœba, the most structureless of organisms, suffers contractions. Ritter

discovered that the *sensitive plant* shuts up when electrified, and Burdon Sanderson has shown that this property extends to other vegetables, being exhibited by the *carnivorous plant*, the Dionæa, or Venus's Fly-Trap.

Animal Electricity.—Although, in his later writings at least, Galvani admitted that the electricity thus operating arose from the metals employed, he insisted on the existence of an *animal electricity* resident in the muscular and nervous structures. He showed that contractions could be produced without using any metals at all by merely touching a nerve at two different points along its length with a morsel of muscle cut from a living frog; and that a conductor of one metal when joining a nerve to a muscle also sufficed to cause contraction in the latter. Galvani and Aldini regarded these facts as a disproof of Volta's contact-theory. Volta regarded them as proving that the contact between nerve and muscle itself produced (as in the case of two dissimilar metals) opposite electrical conditions. Nobili, later, showed that when the nerve and the muscle of the frog were respectively connected by a water-contact with the terminals of a delicate galvanometer, a *current* is produced which lasts several hours: he even arranged a number of frogs' legs in series, like the cells of a battery, and thus increased the cur-

rent. Matteucci showed that through the muscle alone there is an electro-motive force. Du Bois Reymond has shown that if the end of a muscle be cut across, the *ends* of the muscular fibres of the transverse section are negative, and the *sides* of the muscular fibres are positive, and that this difference of potential will produce a current even while the muscle is at rest. To demonstrate this he employed a fine astatic galvanometer with 20,000 turns of wire in its coils; and to obviate errors arising from the contact of the ends of the wires with the tissues *unpolarizable electrodes* were used, made by plunging terminal zinc points into a saturated solution of sulphate of zinc, contained in a fine glass tube, the end of which was stopped with a porous plug of moistened china clay. The contraction of muscles also produces currents. These Du Bois Reymond obtained from his own muscles by dipping the tips of his fore-fingers into two cups of salt water communicating with the galvanometer terminals. A sudden contraction of the muscles of either arm produced a current from the contracted toward the uncontracted muscles. Dewar has shown that when light falls upon the retina of the eye an electric current is set up in the optic nerve."—(*Silvanus Thompson.*)

Volta's Law of Contact.—"The contact of two metals and, most generally, of any two heterogene-

ous bodies, suffices to establish between these bodies a difference of potential. This difference depends upon the nature of the bodies and upon their temperature, etc."

The Pile.—Take a plate of copper, and a plate of zinc. Immerse them in acidulated water, then take another vessel similar in all respects to this one, with copper and zinc plates immersed, connect the first zinc with the second copper with a copper wire, and a simple pile will be formed. The wire from the first copper will have + electricity, and the wire from the last zinc will be —. Thus may any number of cells be united, beginning with the first zinc and the second copper. Then the electrode which will be connected with the first copper will be positive, and that connected with the last zinc will be negative. The molecule of water being separated, the oxygen part (negative) goes to the zinc, and the hydrogen (positive) to the copper. It is impossible to state whether the chemical action is the result of electricity or *vice versâ*, but one thing is certain, pure zinc is not acted on by the liquid unless another conductor, as copper, completes the circuit. Outside the cell the current flows from the copper to the zinc, but inside of the cell it flows from the zinc to the copper, so that here the zinc is positive and the copper negative; hence, the electro-motive force of the cell is

the difference of potential between the zinc and the copper. The electro-motive force of a battery depends entirely upon the nature of the metals used and their temperature, and not upon the size of the plates; it may be observed, however, that the internal resistance of the cell is diminished by using large plates. In batteries composed of copper and zinc plates immersed in acidulated water, we have a counter electro-motive force between the negative copper (copper being negative inside the cell) and the positive hydrogen. The current is thus weakened by the two electro-motive forces in opposite directions, so various inventions have been made to overcome this, of which the best known is the porous cup, containing sulphate of copper, which absorbs the hydrogen as in the Daniell's cell. This is what is known as a *constant* cell.

Theoretic Conditions of a Perfect Pile.—

1. Great electro-motive force.
2. A feeble and constant interior resistance.
3. The electro-motive force to be constant.
4. Cheapness.
5. Practical arrangement of the cells so that they can be easily cleaned.

Choice of Cells.—I consider the best cells for general use the *Leclanché* and the *Law*, with a decided preference for the former. The Leclanché cell of the Gonda pattern gives little trouble, is

constant, lasts for a long time, has a small internal resistance, does not waste, and has no local action. The distinctive features of the Leclanché pile are a zinc-carbon cell and an exciting fluid of sal ammoniac. To prevent polarization, the carbon plate is packed inside a porous pot along with fragments of carbon and powdered binoxide of manganese, which yields up oxygen and destroys the hydrogen bubbles.

NAMES, ELEMENTS, AND FLUIDS OF THE DIFFERENT BATTERIES.

Name of Cell.	Positive Element.	Negative Element.	Exciting Fluid.	Depolarizing Fluid.	E. M. F. in Volts.	Internal Resistance in Ohms.*
Bunsen.	Zinc.	Graphite.	Sulphuric acid dilute.	Nitric acid.	1.8	.08 to .11
Do.	"	"	"	Chromic acid.	1.8	.1 to .12
Chromic acid, single fluid.	"	"	Sulphuric acid and chromic acid, dilute mixed.	None separate.	2.2	.001 to .08
Daniell.	"	Copper.	Zinc sulphate sol.	Copper sulphate sol.	1.079	2. to 5
Fuller.	"	Graphite.	Chloride of zinc solution.	Potash bichromate and hydrochloric acid.	1.5	0.5 to 0.7
Gaiffe.	"	Silver.	Zinc chloride.	Silver chloride.	1.02	0.5 to 0.6
Grove.	"	Platinum.	Sulphuric acid dilute.	Nitric acid.	1.96	.1 to .12
Lalande Chaperon.	"	Copper or iron.	Caustic potash solution.	Oxide of copper.	0.98	1.30
Latimer Clark.	"	Pure mercury.	Sulphate of mercury.	None separate.	1.457	0.3 to 0.5

* The resistances were measured in cells standing 6″ × 4″.

NAMES, ELEMENTS, AND FLUIDS OF THE DIFFERENT BATTERIES.—*Continued.*

Name of Cell.	Positive Element.	Negative Element.	Exciting Fluid.	Depolarizing Fluid.	E. M. F. in Volts.	Internal Resistance in Ohms.*
Leclanché.	Zinc.	Graphite.	Ammonium chloride sol.	Manganese dioxide.	1.6	1.13 to 1.15
Maiche.	Zinc scraps, in bath of mercury.	Platinized carbon.	Common salt solution.	None separate.	1.25	1. to .2
Mariè Davy.	Zinc.	Graphite.	Sulphuric acid dilute.	Paste of sulphate of mercury.	1.52	.75 to 1.
Niaudet.	"	"	Common salt solution.	Chloride of lime.	1.5 to 1.6	5 to 6.
Poggendorf.	"	"	Saturated sol. of potash, bichromate, and sulphuric acid	None separate.	1.98	.001 to .08
Schanschieff	"	"	Mercurial solution.	None separate.	1.56	.05 to 0.75
Skrivanow.	"	Silver.	Caustic potash.	Chloride of silver.	1.5	1.5
Smee.	"	Platinized silver.	Sulphuric acid dilute.	None.	0.47	0.5
Walker.	"	Platinized graphite.	"	"	0.66	0.4
Warren de la Rue.	"	Silver.	Sal. ammoniac sol.	Silver chloride.	1.	0.4 to 0 6

* The resistances were measured in cells standing 6″ × 4″.

Controller.—The instrument shown in Fig. 8, invented by Dr. Massey, is the best one for the general purposes of the practitioner, and from personal acquaintance with it, I commend it highly. It consists of a porcelain plate, provided with a tapering area of soft pencil mark, broadening and thickening up to the point at which the graphite,

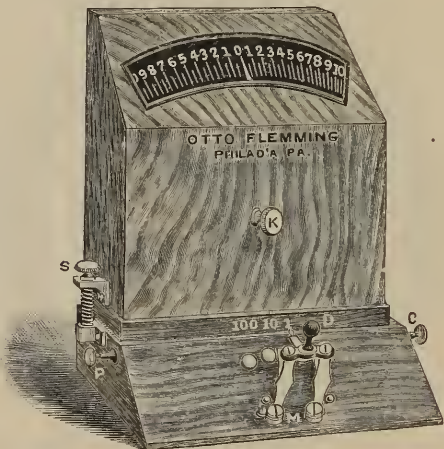
now covered with nickel plating, is connected with the circuit by means of a broad spring contact. This area acts as a resisting material, over which a brass contact, attached to a crank, can be made to pass. When the crank (1, Fig. 8) is placed to the

Fig. 8.

right of the hard-rubber bridge, 2, the contact rests entirely on the porcelain and the circuit is broken. Moving it slightly in the direction of the arrow, it soon touches the graphite mark, and permits the least amount of current to pass through.

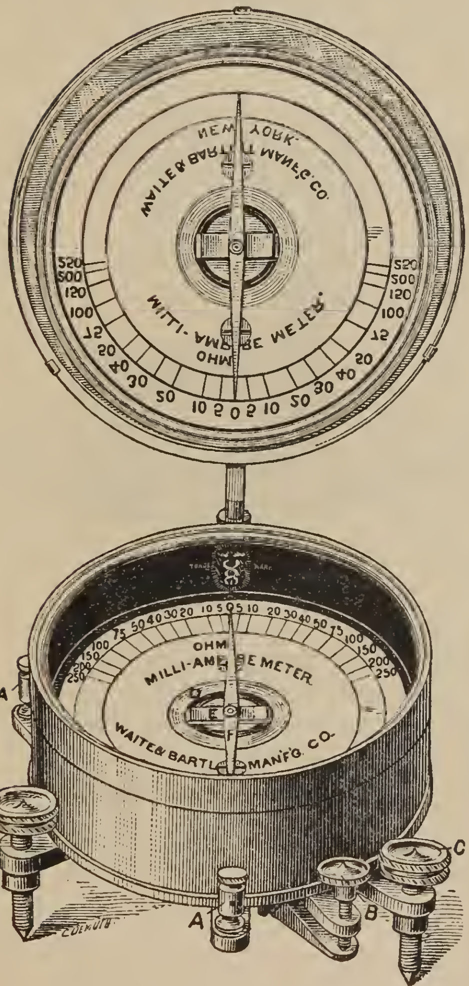
The Meter.—Without a good instrument for measuring the strength of a current, no truly scientific, reliable or encouraging work can be done in electricity. Figs. 9 and 10 are about the best on the market. I confess a preference for the horizontal one—an instrument which is "dead beat" in

FIG. 9.



action (that is, in which the number of vibrations is reduced to a minimum), is very desirable in neurological work especially. However, both of these instruments are reliable, and both will give satisfaction. The limits of this book do not permit me

Fig. 10.

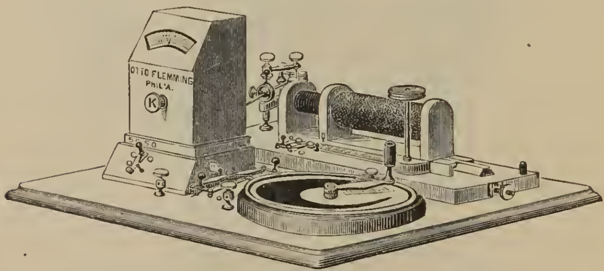


to enter into a study of the theory of galvanometers and the steps of their manufacture.

BATTERIES.

Portable.—Both of the batteries made by Waite & Bartlett and by Flemming are most admirable

FIG. 11.



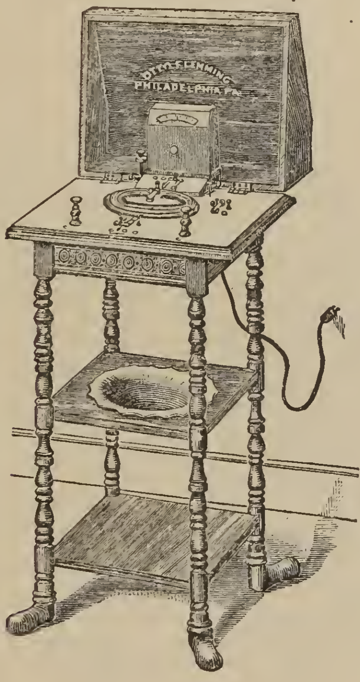
MASSEY'S COMPLETE ELECTRO-GYNÆCOLOGICAL APPARATUS.

and really will answer perfectly well for even the office use of the general practitioner.

How to Bring the Battery into Action.—Raise up the cells by means of the cross-piece until the zincs are immersed in them, then bring the controller and the meter into the circuit as shown in Fig. 13. Now bring all of the cells of the battery into action and regulate the current by moving the

handle of the controller slowly, until the galvanometer registers the required strength—the cir-

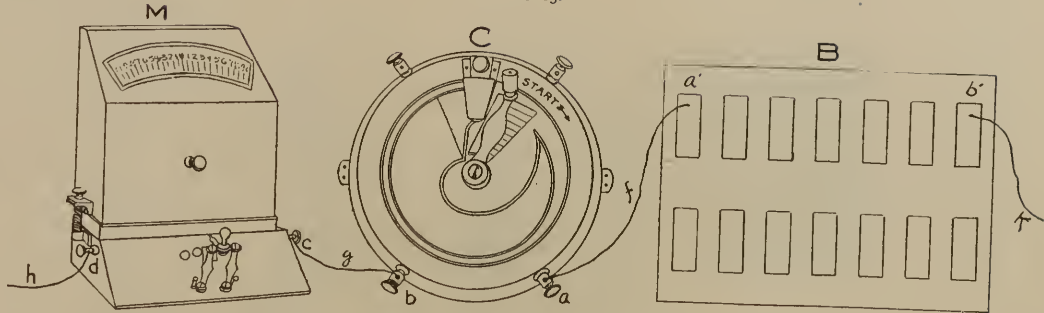
FIG. 12.



MASSEY'S BED-SIDE TABLE.

cuit being completed, of course, by the patient to whom the electrodes have been applied.

FIG. 13.

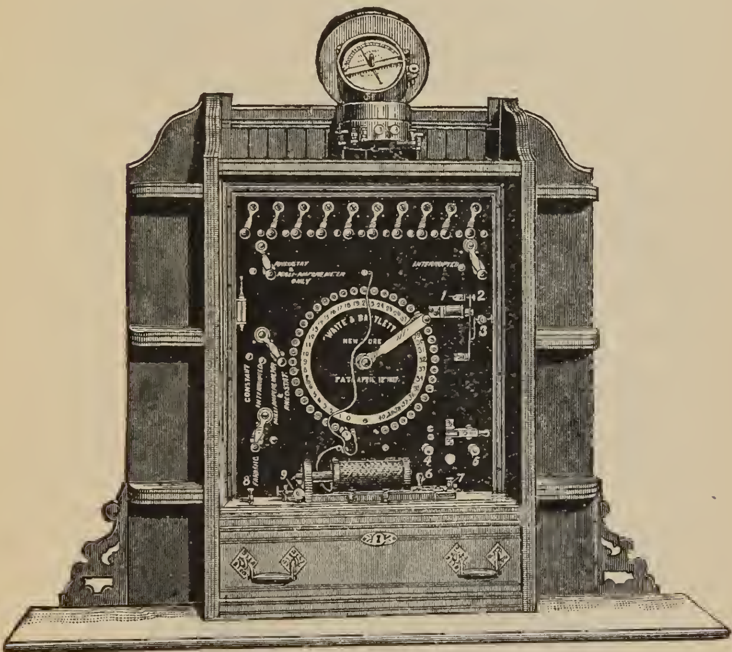


B, battery. *C*, controller. *M*, meter. (*f*) wire leading from battery (*a'*) to binding post (*a*), thus connecting the controller. (*g*) wire leading from binding post (*b*) of controller to binding post (*c*) of meter. (*h*) conducting wire from binding post (*d*) of the meter, to which one electrode is attached. (*k*) conducting wire from the last cell of the battery, to which the other electrode is attached.

CABINET BATTERIES.

This admirable arrangement (Fig. 14) is supplied with the Gonda cells—with the Induction or

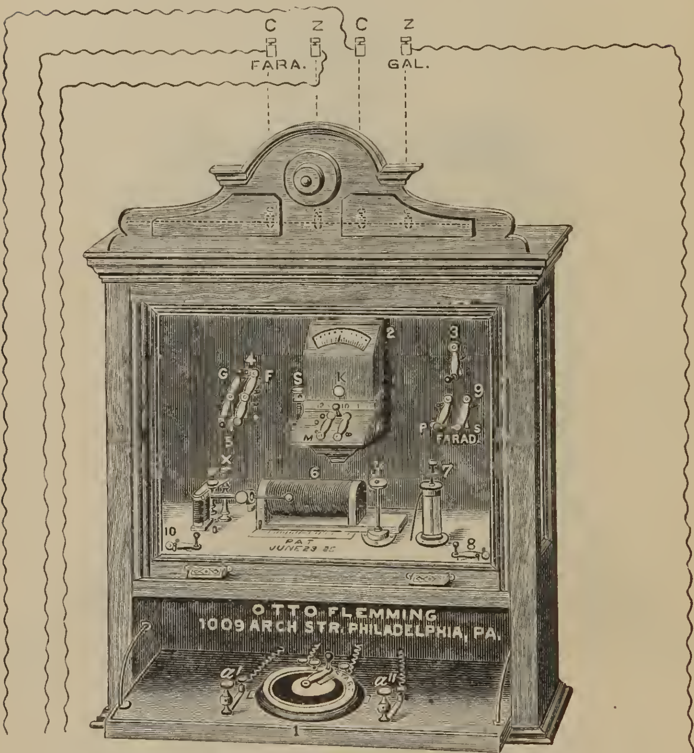
FIG. 14.



Faradic coil—with current changers, interruptors, switch-board, etc.

Fig. 15 is made by Flemming, and is supplied with Massey's controller, faradic coil, galvanometer, etc. The simpler the arrangement of a cabinet

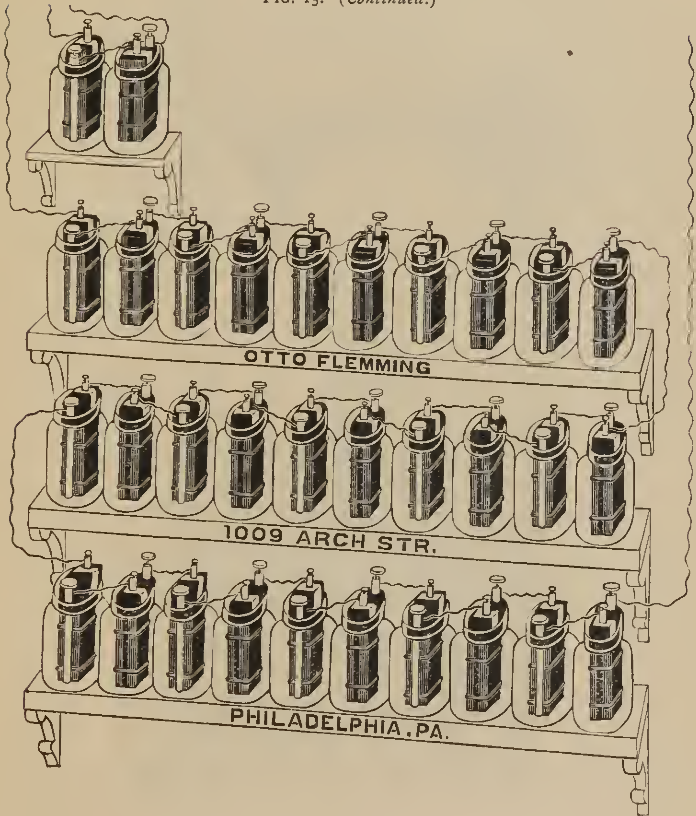
Fig. 15.



See continuation of this figure on page 55.

battery the more useful it becomes. The tendency to a great complexity and multiplication of

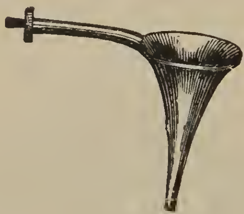
FIG. 15. (*Continued.*)



switches I regret, because they are always sure to be more or less confusing.

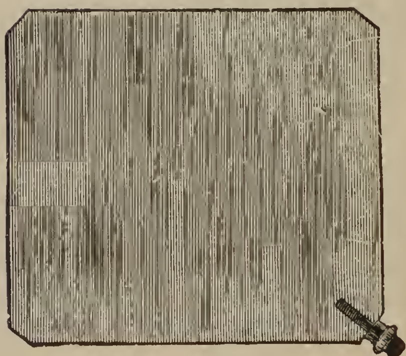
ELECTRODES.

FIG. 16.



ANAL ELECTRODE.

FIG. 17.



FOOT PLATE.

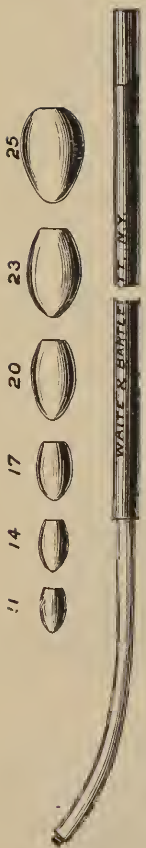


FIG. 18.—DR. FRY'S INTRA-UTERINE ELECTRODE FOR STENOSIS.

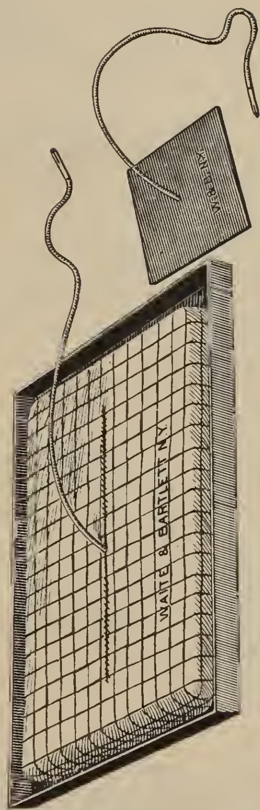


FIG. 19.—APOSTOLI'S CLAY ELECTRODE, WITH PAN AND PLATE.

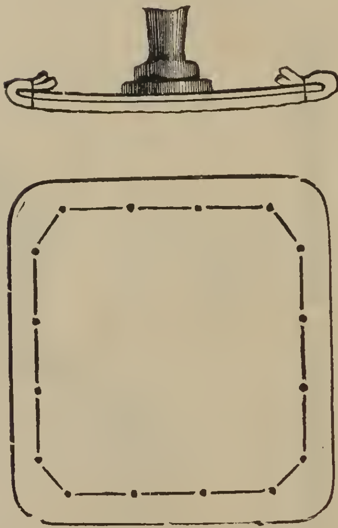


FIG. 20.—SECTION OF LARGE HAND ELECTRODE.

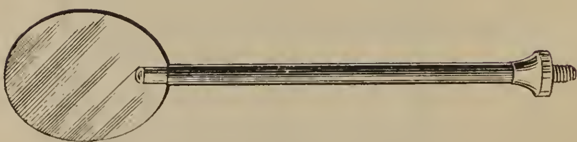


FIG. 21.—TONGUE PLATE.

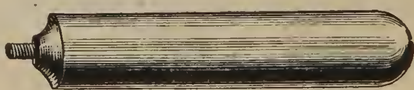


FIG. 22.—VAGINAL ELECTRODE.

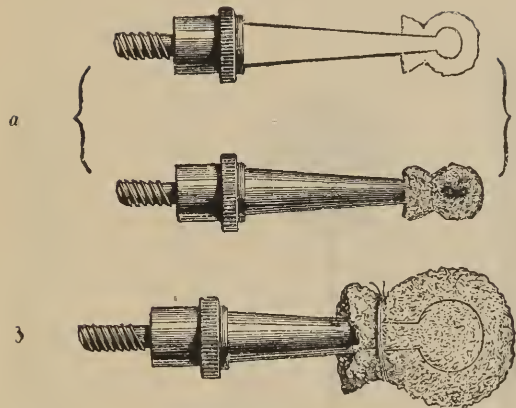


FIG. 23.—SPONGE ELECTRODE.

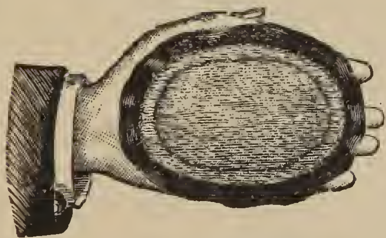


FIG. 24.—FLEXIBLE ELECTRODE.

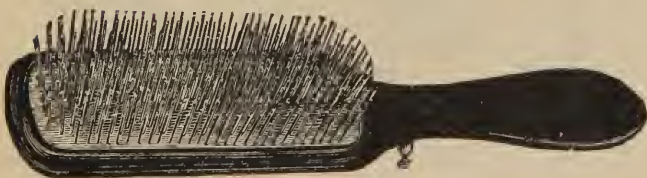


FIG. 25.—BRUSH ELECTRODE.

FIG. 26.—APOSTOLI'S PLATINUM ELECTRODE FOR PUNCTURE.

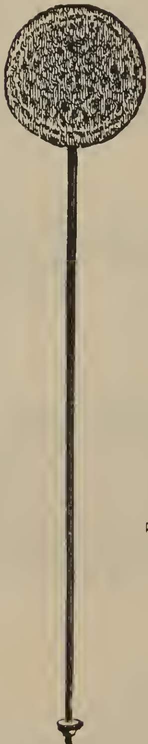


FIG. 27.—LONG-STEM SPINAL ELECTRODE.

FIG. 28.—UNIVERSAL ELECTRODE FOR THROAT.

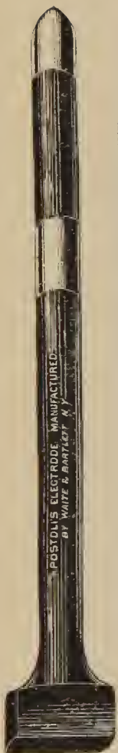


FIG. 29.—APOSTOLI'S BI-POLAR ELECTRODE FOR FARADIC CURRENT.

FIG. 30.—RECTAL ELECTRODE.

FIG. 31.—APOSTOLI'S BI-POLAR ELECTRODE FOR INTRA-UTERINE FARADIZATION.

FIG. 32.—MASSEY'S SPIRAL PLATINUM ELECTRODE.

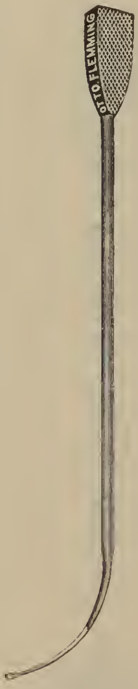


FIG. 33.—MASSEY'S STIFF PLATINUM ELECTRODE.

FIG. 34.—MASSEY'S GOLD-TIPPED PUNCTURE NEEDLE.

CHAPTER IV.

FARADIC OR INDUCED CURRENT.

In 1831 Faraday discovered that currents can be induced in a closed circuit by moving magnets near it, and he also discovered that a current whose strength is changing may induce a secondary current in a closed circuit near it. Such currents are known as *Induction Currents.* The action of a magnet or current in producing such induced currents is termed *electro-magnetic* induction.

Magnetic Induction Currents.—Insert a magnet into the hollow of a coil of insulated wire; a current is immediately caused as the magnet enters. If the magnet remain motionless no current is produced. Now withdraw the magnet rapidly and a current is established, which flows in a direction opposite to the one which was caused by the insertion of the magnet. The first induced current is called an *inverse current*, and the second is the *direct current.*

Induction Currents produced by Currents.—Connect to a battery a small coil of stout wire, and connect to the galvanometer another coil. On sliding the smaller or "*primary*" coil into the larger or

"*secondary*" coil, a momentary inverse current is produced, and upon removing the same we have a direct current (*i. e.*, a current which runs the same way around the outer secondary coil as the primary current of the inner coil). If the circuit be broken while the primary coil lies within the secondary, we have an effect similar to that which would take place if the primary coil were suddenly removed to an infinite distance. *Making* the battery circuit while the primary coil lies within the secondary produces the same effect as plunging it suddenly into the coil.

The Induction Coil.—"The induction coil consists of a cylindrical bobbin having a central iron core surrounded by a short inner or 'primary' coil of stout wire, and by an outer 'secondary' coil consisting of many thousand turns of very fine wire, very carefully insulated between its different parts. The primary circuit is joined to the terminals of one or more cells, and in it are also included an interruptor, and a commutator or key. The object of the interruptor is to make and break the primary circuit in rapid succession. The result of this is at every 'make' to induce in the outer 'secondary' circuit a momentary inverse current, and at every 'break' a powerful momentary direct current. The currents at 'make' are suppressed, as explained below: the currents at 'break' manifest themselves

as a brilliant torrent of sparks between the ends of the secondary wires when brought near enough together. The primary coil is made of stout wire, that it may carry strong currents, and produce a powerful magnetic field at the centre, and is made of few turns to keep the resistance low, and to avoid self-induction of the primary current on itself. The central iron core is for the purpose of increasing, by its great coefficient of magnetic induction, the number of lines of force that pass through the coils: it is usually made of a bundle of fine wires to avoid the induction currents, which if it were a solid bar would be set circulating in it, and which would retard its rapidity of magnetization or demagnetization. The secondary coil is made with many turns, in order that the coefficient of mutual induction may be large; and as the electro-motive force of the induced currents will be thousands of volts, its resistance will be immaterial, and it may be made of the thinnest wire that can conveniently be found . . . The interruptors are usually self-acting . . . A common one for small coils is a 'break,' consisting of a piece of thin steel which makes contact with a platinum point, and which is drawn back by the attraction of the core on the passing of a current, and so makes and breaks circuit by vibrating backward and forward, just as does the hammer of an ordinary electric bell."

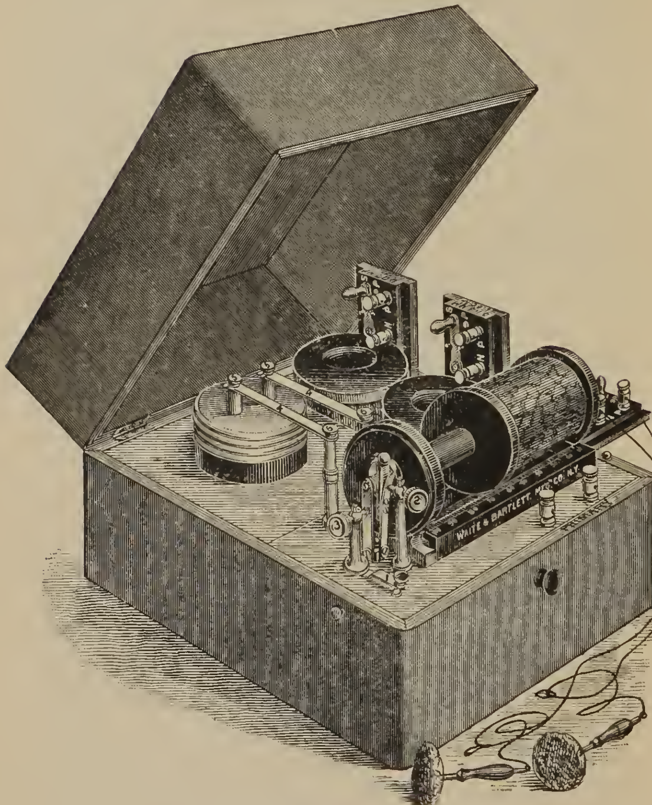
Self-Induction — Extra Currents. — Now, if two circuits approach one another so as actually to coincide, the *mutual* induction becomes a *self-induction* of the circuit on itself. The existence of self-induction in a circuit is attested by the so-called *extra-current*, which makes its appearance as a bright spark at the moment of breaking circuit. If the circuit be a simple one, and consist of a straight wire and a parallel return-wire, there will be little or no self-induction; but, if the circuit be coiled up, especially if it be coiled around an iron bar, as in an electro-magnet, then on breaking circuit there will be a brilliant spark, and a person holding the two ends of the wires between which the circuit is broken may receive a slight shock, owing to the high electro-motive force of this self-induced extra current. The extra current due to self-induction on "making" circuit is an inverse current, and gives no spark, but it prevents the battery current from rising at once to its full value. The extra current on breaking circuit is a direct current, and therefore increases the strength of the current just at the moment when it ceases altogether.

Of the Primary and Secondary Coil.—I some time ago made the assertion that I quite agreed with Tripier, Apostoli and others in regarding the current of the "primary," or thick wire, as differing in its effects from that produced by the "secondary,"

or fine wire. Rohé and Liebig, following Dr. Massey, look upon the assertion as unfounded. Longer and continued experience does not induce me to alter this opinion. All clinical evidence seems to be in my favor, as does also the fact of the very structure of the coil. The current of the "primary" is a strong current, with a powerful magnetic field at its centre; it has a low resistance and no self-induced current. Its physiological effects are quite different from those of the secondary coil. Questions of interposed resistance, of electro-motive force and of the powerful magnetic field of the primary seem to sustain me in this belief. In my hands, the secondary current is much more useful for quieting pain than is the primary; while, on the other hand, muscular contractions are more regularly induced by the primary current. I believe, however, that in the static induced current we may have a current better than either of these.

The chloride of silver batteries, made by the John A. Barrett Co., of Baltimore, and by the McIntosh Co., of Chicago, are most admirable. They are clean, portable, and are characterized by great constancy. For ordinary office work, a fifty-cell chloride of silver battery will answer every purpose. Having used batteries made upon this principle for a long time, and having seen the hard usage to which they have been subjected in a

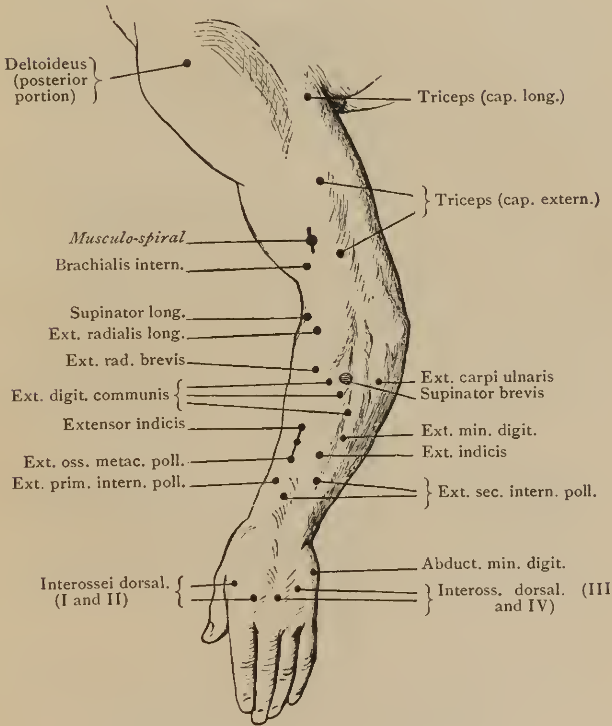
FIG. 35.



ENGELMANN'S FARADIC BATTERY, WITH THREE COILS.

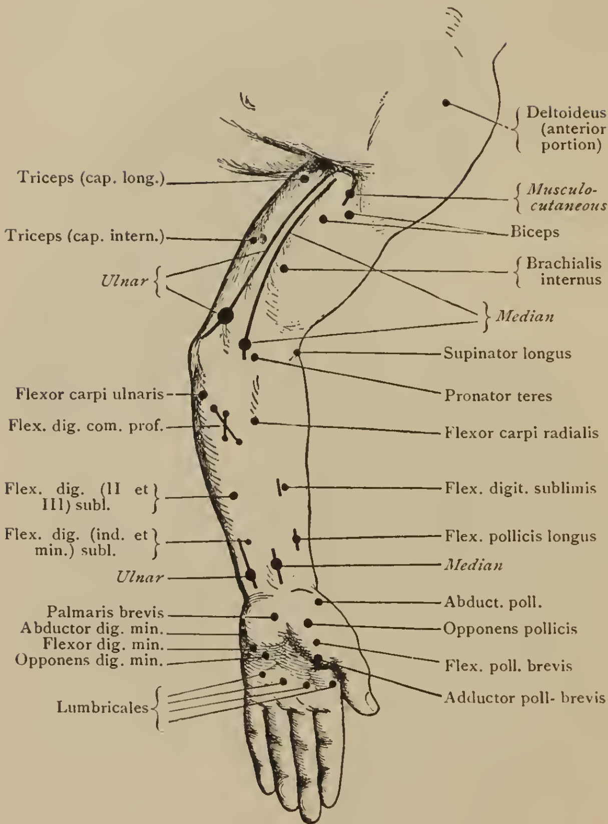
large dispensary practice, without any apparent loss of value, I am very glad to give them a cordial

FIG. 36.



MOTOR POINTS OF DORSAL ASPECT OF LEFT ARM.

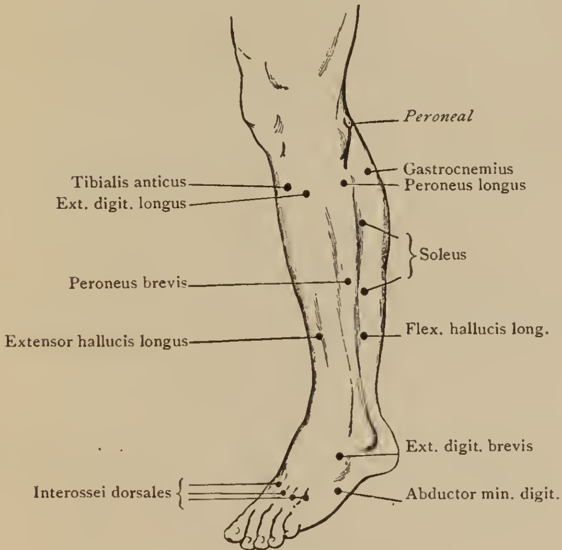
Fig. 37.



MOTOR POINTS OF INNER ASPECT OF LEFT ARM.

endorsement. The same praise may very properly be given to the chloride of silver Faradic battery, made by the Barrett Co., of Baltimore, which is

FIG. 38.

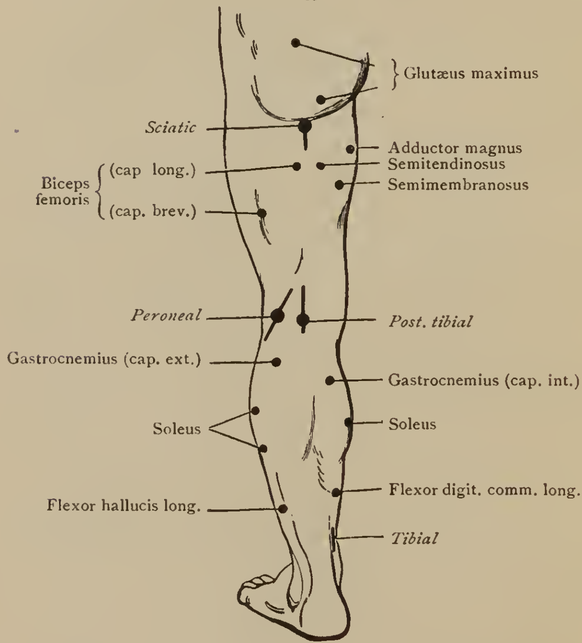


OUTER ASPECT OF LEFT LEG.

small, neat and portable. Perhaps I should not be far wrong in saying that it would the best subserve the uses of the general practitioner, and is the one from which he would derive the most satisfaction.

If the physician desires a more perfect demonstration of the different effects to be obtained from the

FIG. 39.



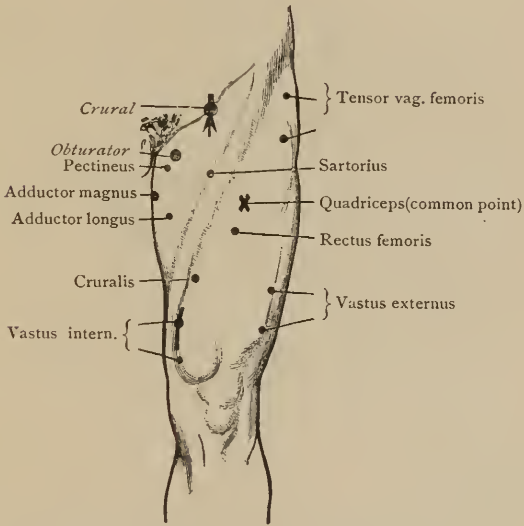
MOTOR POINTS OF POSTERIOR ASPECT OF LEFT THIGH AND LEG.

primary and secondary coils of the Faradic battery, he should ask the manufacturer to make at least 2000 turns of fine wire on the secondary bobbin,

which will give a most soothing and quieting current.

It should be remembered that the primary coil of coarse wire of the Faradic battery is the only

FIG. 40.

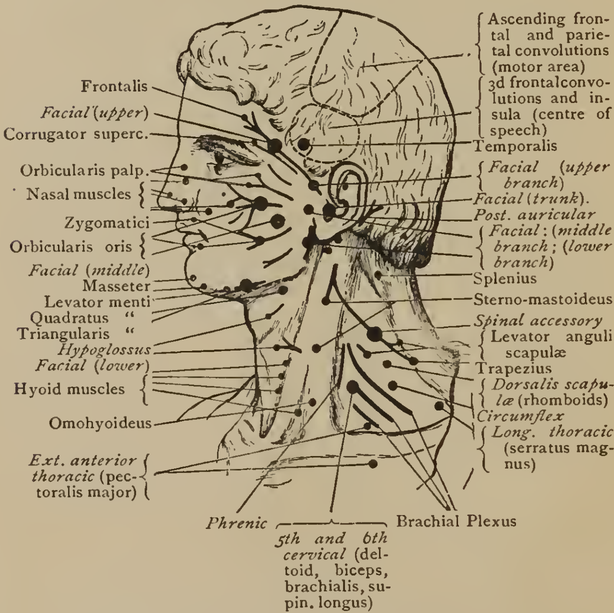


MOTOR POINTS OF ANTERIOR ASPECT OF LEFT THIGH.

one that is connected with the cell originating the current, and that the current of the secondary or fine wire coil is purely a current of induction. Duchenne was the first writer to point out the distinct physical and physiological differences between

the primary and secondary. The secondary current is a "to and fro" one, and when generated from a bobbin having a large number of turns of

FIG. 41.

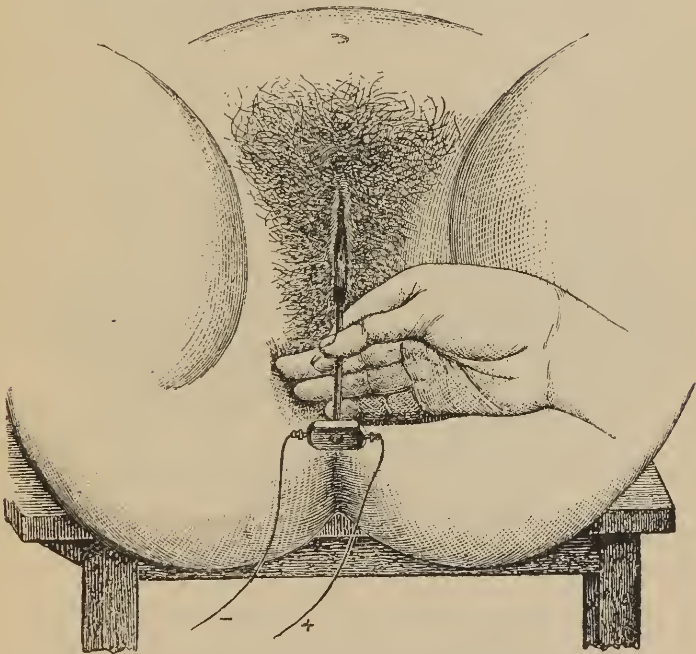


MOTOR POINTS OF FACE AND NECK.

fine wire, the sensation engendered is very similar to that produced by the Static induced current, and is entirely different from the sensation occasioned

by the primary. In ovarian pain the patient cannot tolerate the primary current, but experiences immediate relief from an application of the sec-

Fig. 42.

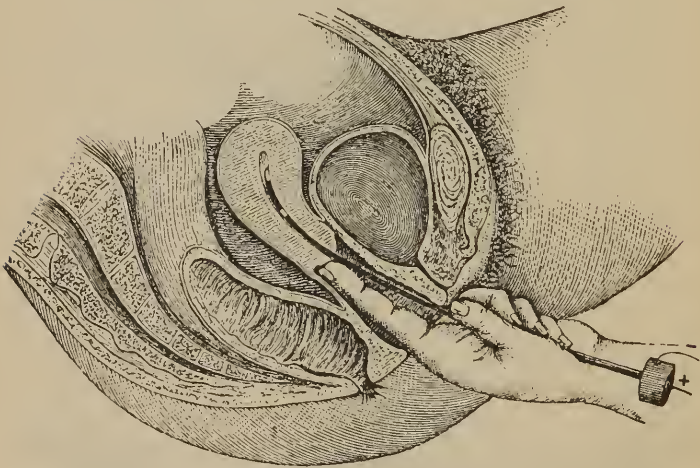


APOSTOLI'S BI-POLAR UTERINE FARADIZATION.

ondary. That is, the "tension" of the current, is entirely different. It is a current of magnetization and demagnetization, something akin to the

oscillations of the Static. The primary is feebly galvanic, the secondary is not at all so. The primary current is much more pronounced in producing muscular effects—the secondary is seen to best advantage in relieving pain. Engelmann's inven-

Fig. 43.



ELECTRODE IN POSITION.

tion, a cut of which is given, has three coils, the third coil giving, of course, a current of tension more distinct than the primary or secondary. Here the current of the secondary is opposite in direction to that of the primary, while the current of the tertiary is opposite to the secondary.

THERAPEUTIC INDEX.

Abscess.—Faradization and galvanization hasten suppuration. Open with galvanic acupuncture.

Accommodation.—*Troubles of paralysis of ciliary muscle.* Moist faradization of the globe of the eye, negative, close circuit in hand of same side. Primary current; 2 to 3 minutes sitting.

Spasm of ciliary muscle. Positive, continuous galvanization. Posterior pole to globe of eye; circuit closed by the hand; very weak current; 10 to 15 minutes sitting.

Acne.—See Skin.

Adenitis (chronic).—Moist faradization; tumor held between both excitants; primary current; 5 to 10 minutes sitting.

Alcoholism.—Ascending galvanization of spinal cord; 3 minutes; medium current.

Amenorrhœa.—In virgins lumbar sub-pubic faradization; séance, 10 to 15 minutes; primary current. Central and sub-aural galvanization, and spinal galvanization, and intra-uterine negative galvanization are all useful.

Amygdalitis.—Continuous galvanization, and in chronic forms + or — puncture of the tonsil.

Analgesia.—Dry faradization, or static spark, to analgesic surface.

Anaphrodisia.—*Due to excessive cerebration.* Ascending spinal galvanization; medium current; 3 to 5 minutes.

From insufficient spinal action. Faradization or static induction, one pole in the perineum, the other in the rectum.

Anæmia.—Static bath and spark. Ascending spinal galvanization.

Aneurism. + needle in the tumor, and a large electrode near it, protecting the parts carefully from cold. Séance 7 to 20 minutes.

Angina of the chest. Energetic faradization; revulsive about the breast. Galvanization of the left cardio-cervical region; large + electrode over the head; — electrode over the left pneumogastric at its sortie from the inferior sterno-mastoid attachments.

Anchylosis.—Active faradization and static current.

Aphonia.—Place one electrode of the static or faradic over the crico-thyroidean space, the other at the nape of the neck; mild current; 1 to 2 minutes; also excitation of same current with wet electrodes, one electrode in the crico-thyroid space, and the other over the crico-thyroid cartilage. + galvanization with laryngeal electrode, the circuit being closed at the nape of the neck, or with the hand. 3 minutes.

Arthritis.—*Chronic.* Faradization or static induction, with the two electrodes at the transverse diameter of the joint; low currents; 5 to 10 minutes. Strong galvanic currents may be used to cause absorption of any effusion. Electro-massage is often excellent.

Ascites.—Deep — rectal faradization, the circuit being closed with a large moist abdominal electrode. 5 to 10 minutes.

Asphyxia in general.—Thoracic faradization. Faradization of the diaphragm by the phrenic nerves, that are accessible, at the neck, upon the anterior face of the anterior scalenus muscle, by manipulating the clavicular border of the sterno-cleido-mastoid, an electrode over each nerve and current rapidly interrupted. Primary current; static baths.

Biliary Colic, mild form.—Static induction or faradization over the liver. + galvanization, closing circuit with the hand, or over the right pneumogastric nerve.

Blepharoptosis.—*Spinal.* — olive faradic electrode placed in the internal part of the orbital depression of the superior eyelid, the + closing the circuit at the back of the neck. 1 to 2 minutes.

Bronchitis (chronic).—Thoracic static induction.

Callosities.—Painful. Static spark, or faradization, the swelling being compressed between the electrodes.

Cancer.—Electrolysis. Galvano-cautery. — galvanization, interrupted; with large electrode, active, over the cancer, as commended by Parsons.

Catalepsy.—Galvanization, sacro-post-cervical.

Cataract.—Galvanization of the globe of the eye, circuit closed with hand of same side.

Cephalalgia.—*Congestive.* Faradization, primary, the electrodes being placed on the temples. Medium current; 3 to 5 minutes.

In *dyspeptic hemicrania*, galvanization, ascending, of the right pneumogastric. 3 minutes; medium current.

In *gouty hemicrania.* + galvanization; large tampon over frontal region; circuit closed by the hand.

Chlorosis.—Lumbar-pubic faradization or uterine faradization. Daily sittings 10 minutes at first, then 5.

Chorea.—Ascending spinal galvanization; 3 minutes; mild current; increase to 5 and 15 minutes. In young girls add to this lumbar pubic faradization.

Colic.—*Flatulent* or *dyspeptic.* Moist abdominal faradization; active over iliac fossæ. 3 to 5 minutes.

Nervous. Revulsive skin faradization of abdominal wall.

Saturnine. Same.

Nephritic. Galvanization, lumbar post-cervical. During the crisis, faradization; 10 minutes. One electrode over kidney, the other over hypogastric region. Toward the close of the crisis, the same application for 3 or 5 minutes.

Hepatic. Galvanization, right precervical region. During crisis as above (faradization), one tampon over gall duct, the other over right post-thoracic region.

Conjunctivitis. + galvanization, circuit closed on the neck. 5 to 10 minutes; feeble current. Double points of static oculo-post-cervical.

Constipation.—Lumbar post-cervical galvanization. 15 to 30 minutes.

Atonic. Abdomino-rectal faradization. 3 to 5 minutes; primary current.

Recto-epigastric galvanization. 5 minutes; medium current.

Contractions.—Static spark. Galvanization +.

Contusion.—*Recent.* Faradization. 5 to 10 minutes; primary.

Convulsions.—*Ataxic.* These are usually symptoms of central symptomatic disorders akin to cerebral paralyses and galvanization of the nervous centres, the bulb being regarded on the common centre, may be tried.

Cough.—*Whooping.* Epigastric-pre-cervical (right). Galvanization; 3 minutes; twice a day after eating.

Cornea.—(*Ulcerations, etc.*). Galvanization on globe of eye; circuit closed by the hand; ½ to 2 milliampères. 5 minutes.

Coryza. · + Galvanization over nose; circuit closed by hand. Feeble current; 10 to 15 minutes.

Cramp.—*Writers'.* Centripetal galvanization. + over dorsal aspect of finger. — over neck. 3 to 5 minutes, daily. Galvanization of cerebro-spinal system. Faradization; massage of muscles.

Cretinism.—Static needle discharge over neck. Spinal galvanization.

Cyanosis (cardiac).—General faradization; 10 minutes. Galvanization of the cardio-pre-cervical region of pneumogastric.

Cystitis.—*Acute.* + galvanization. + pole at pubis or perineum; negative pole at feet or in hand. 5 to 10 minutes.

Chronic. Vesical faradization. — pole in bladder or at pubis; positive at perineum. Primary current; 3 minutes.

Cystocele.—Primary faradization; vaginal. Circuit closed at pubis; 3 minutes. Results unsatisfactory.

Delirium Tremens.—Galvanization. + pole on sacrum; negative at neck. 5 minutes; medium current strength.

Diabetes.—Spinal galvanization, ascending, 3 to 5 minutes, to quiet symptoms.

Diarrhœa.—*Accidental.* Abdominal faradization, primary; 3 to 5 minutes.

Chronic. Revulsive faradization, abdominal.

Diphtheria.—(?)

Dysmenorrhœa.—Uterine faradization, bipolar. In virgins lumbo-abdominal, primary; 3 to 5 minutes.

Obstructive from stenosis. Galvanization; Fry's electrodes.

Membranous. Intra-uterine + galvanization.

Dyspepsia.—*Gastric.* Galvanization, right pneumogastric. Positive pole over epigastrium, negative over the nerve when in front of the neck, or at the back of neck. 3 minutes; 8 to 15 milliampères.

Intestinal. Abdomino-rectal faradization.
Abdominal post-cervical galvanization.

Dysphagia.—Epigastro-cervical (post) galvanization; + pole over epigastrium, — pole at neck. 3 minutes; 5 to 10 milliampères.

Dysuria.—Galvanization; + pole at perineum; circuit closed by hand, abdomen or feet.

Eclampsia.—Spinal galvanization.

Epilepsy.—Galvanization; — pole at neck, the + pole where the patient feels the *aura.* 5 minutes. Faradization sometimes gives great relief.

Fibroma.—Galvanic puncture, according to principles laid down by Apostoli. See "Gynæcological Electro-therapeutics," Bigelow.

Galactorrhœa.— + galvanization of breasts; circuit closed by the hand.

Gastralgia.—Galvanization; + pole over epigastrium; negative pole in front of neck where the right pneumogastric enters the inferior borders of the sterno-mastoid. 3 minutes; mild current. Very useful in painful gastralgia with nausea. Supplement this with cutaneous faradization over epigastrium.

Gastrorrhœa.—Same.

Glaucoma.— + galvanization of globe of eye; circuit closed by the hand, with poles (moist) applied to eyelids, which should be closed.

Goitre.—Negative puncture.

Cystic. Cauterization negative.

Exophthalmic. + galvanization of tumor; circuit closed by hand.

Gout.—Primary faradization of painful articulation. Static spark.

Hemoptysis.—In women at critical period. Intra-uterine faradization; primary current.

In men, lumbo-abdominal faradization.

Hemorrhoids.—Positive puncture.

Hernia.—After reducing, replace finger with a moist, negative, olive-pointed electrode, with positive pole in rectum. Faradization, primary; 3 to 5 minutes.

In double inguinal hernia place electrodes in the rings.

In irreducible hernia use large, flat electrode instead of the olive-pointed one.

Hydrocele.—Negative galvanic puncture; close circuit on internal part of thigh, as practiced by Walling and others.

Hydronephrosis.— + galvanization of lumbar region as a palliative; close circuit on dorso-cervical region.

Hyperæmia.—Faradization. (?)

Hyperæsthesia.—*General.* Ascending spinal galvanization.

Local. + galvanization.

Hysteria.—Treat according to symptoms. Look to general health and state of uterus.

Incontinence *of Urine.*—Faradization; negative pole on pubis, positive on perineum. Spinal galvanization.

Inertia, *uterine.*—Faradization. If of cerebral origin, ascending spinal galvanization.

Insolation.—Spinal galvanization.

Insomnia.—Faradization localized. Spinal galvanization.

Intestinal.—*Obstruction.* Deep faradization of abdominal mass by rectal electrode; circuit close by large abdominal pole. Primary current; 2 to 5 minutes; sittings frequently repeated.

Interrupted galvanization; abdomino-rectal, — pole in rectum.

Invagination. Faradization as above.

Irritation.—*Spinal.* Faradization; one pole on sacrum, the other

on the neck. Primary current; 3 to 5 minutes; one hour after faradization of skin along the spine, ascending galvanization.

Ischuria.—Centripetal galvanization; + pole on pubis; negative pole over dorsal region. 5 to 10 minutes.

Laryngitis.—Galvanization; + pole over larynx; circuit closed at neck or by the hand.

Lipoma.—Negative puncture.

Lumbago.—Galvanization; large + electrode over the loins; the other a little higher. 3 to 5 minutes.

Menorrhagia.—Galvanization; + intra-uterine, clay electrode on abdomen.

Metritis.—Positive or negative intra-uterine galvanization, as prescribed by Apostoli, according to symptoms. Abdomino-uterine faradization, as prescribed by Tripier. In non-hemorrhagic forms, negative pole in uterus when using galvanic current.

Metrorrhagia.—Intra-uterine galvanization; + pole in uterus.

Morphinism.—Spinal galvanization.

Myelitis.—*Chronic.* Spinal galvanization.

Myodynia.—Galvanization of painful muscles.

Nausea.—Galvanization of both pneumogastrics.

Nymphomania.—Spinal galvanization; weak currents; vaginal faradization with primary current.

Œdema.—Static frictions.

Orchitis.—*Acute.* Galvanization; positive pole on tumor; negative pole on the track of the cord at the external opening of the inguinal canal.

Chronic. Same.

Ovary.—*Ovaritis.* Static induction; bipolar faradization of vagina; bipolar intra-uterine faradization.

Palpitations.—Ascending galvanization of the pneumogastric.

Paralysis.—*If due to cerebral lesion*, longitudinal, transverse and diagonal brain galvanization. If the lesion is in spinal cord, spinal galvanization. In myopathic palsies galvanization; use faradization in those cases where the farado-muscular con-

tractility is preserved; also try static sparks in the treatment of paralyzed muscles. (Read extract from Von Ziemssen, quoted by Rohé and Liebig, pages 294–295.)

Bell's Palsy. Transverse occipital brain galvanization and sub-aural galvanization; then galvanization of nerve trunk; then faradization of nerve, one pole over stylo-mastoid foramen, and the other successively over motor points of paralyzed muscles. Try static sparks along course of nerve. In a general way, it may be said, that galvanism is required for all paralysis, with muscular stimulation by the faradic or static inductive brush.

Photophobia.—Galvanization; + of globe of the eye.

Pleurisy.—*Chronic.* Faradization of thoracic wall.

Pollutions.—Ascending spinal galvanization.

Priapism.—Spinal galvanization.

Prostate.—*Simple Hypertrophy.* Recto-urethral faradization.

Retinitis.—*Chronic.* Negative faradization of globe of eye.

Retroflexion and Retroversion of *Uterus.*—Vesico-uterine faradization.

Satyriasis.—Spinal galvanization.

Spinal Cord.—*Chronic Meningitis* and *Pachymeningitis.* Spinal galvanization.

Meningeal Hemorrhage. Same.

Chronic Myelitis. Direct galvanization.

Multiple and *Lateral Sclerosis.* Spinal and sub-aural galvanization; peripheral faradic (skin) stimulation. Avoid faradization in lateral sclerosis.

Locomotor Ataxia. Spinal galvanization; sub-aural galvanization and static electricity to spine. Use static spark for the pains.

Poliomyelitis. (?)

Tic *Douloureux.*— + Galvanization of painful points.

Torticollis.—Longitudinal galvanization of contracted muscles.

Tumors, Fibroid of Uterus.—Puncture with galvanic currents of intensity, negative or positive, as directed by Apostoli; if necessary under ether, 100 to 200 milliampères; 5 minutes.

Definitions.—*Longitudinal brain galvanization.* Large elec-

trodes to forehead and occiput. *Stabile*, when electrodes are held firmly, and *labile* when they are moved about.

Transverse brain galvanization. Electrodes on two sides of frontal bone, temporal bones, and mastoid process. Currents 1 milliampère.

Spinal galvanization, longitudinal. Electrodes over cervical and sacral spinous processes.

Transverse. One pole over the spine, and the other in median line in front.

Sub-aural galvanization. One two-inch electrode at maxillary angle of neck, and pressed toward spine. Other electrode over 5th and 7th cervical vertebræ on opposite side. Current of 5 milliampères.

General faradization. One pole to plate under feet or buttocks, with large sponge attached, and the other to upper extremity.

Local faradization. Use metal electrodes covered with sponge or cotton. Brush electrode for skin.